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MULTIPLE SCATTERING EFFECTS ON TRANSMISSION THROUGH THE ATMOSPHERE-ETC(U)
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This annual report gives a summary of the work completed and underway on the contract covering the period from September 1, 1979 to April 15, 1980. The work is directed to the investigation of the transmission characteristics of optical waves with wavelengths in the range of 1-15 μ m through various atmospheric conditions including clouds, fog, turbulence, rain, hail, snow, and inhomogeneous layers. Progress was made in the areas of plane wave solution, beam wave solution, and pulse wave solution of the optical transmission characteristics through fog.		

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DEPARTMENT OF ELECTRICAL ENGINEERING
University of Washington
Seattle, WA 98195

Annual Summary Report

by

Akira Ishimaru

April 1980

MULTIPLE SCATTERING EFFECTS ON TRANSMISSION THROUGH THE ATMOSPHERE

ONR Contract N00014-78-C-0723

September 1, 1979 to August 31, 1980

Dr. B. R. Junker, Contract Monitor
Code 421
Director, Physics Program
Physical Sciences Division
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217

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1. Principal Investigator: Akira Ishimaru

2. Contract Description

This contract is directed to the investigation of the transmission characteristics of a wave with the wavelengths in the range of 1 μm to 15 μm through various atmospheric conditions including clouds, fog, turbulence, rain, hail, snow, and inhomogeneous layers.

3. Scientific Program

In spite of numerous recent investigations, a complete understanding of the optical transmission characteristics through fog and clouds is still lacking. In particular, the range of validity of the diffusion theory needs to be established, and the transition from single scatter to diffusion should be clarified. The effects of the size distribution and the density are still not clear. The difference between beam waves and plane or spherical waves in discrete scatterers needs to be investigated. The pulse broadening in fog is among the most important as yet unknown aspects of the problem which we wish to vigorously pursue.

4. Scientific and Technical Approach

We have employed the eigenvector technique, Monte-Carlo technique, diffusion theory, and first-order scattering theory. We made use of the two-frequency radiative transfer equation for pulse problems. We have also initiated some experimental study to compare with the experimental results. There is a definite need to compare these theories with the experimental results, and define the range of validity of each theory. We are making a major effort in this direction.

5. Progress

During the past period, we have investigated the transmission and reflection characteristics of a plane wave incident on a plane-parallel medium containing discrete scatterers based on the diffusion theory, and the results are in good agreement with the Monte-Carlo solution. We have also conducted the theoretical and experimental study of an optical beam in discrete scatterers, and a good agreement is observed.

6. Publications

Journal Publications with ONR Sponsorship

1. A. Ishimaru and K. J. Painter, "Backscattered pulse shape due to small-angle multiple scattering in random media," Radio Science, to appear.
2. K. Shimizu, A. Ishimaru, L. Reynolds, and A. P. Bruckner, "Back-scattering of a picosecond pulse from densely distributed scatterers," Applied Optics, 18, 20, pp. 3484-3488, October 1979.
3. K. Shimizu and A. Ishimaru, "An experimental test of the reduced effective velocity of light in a diffuse medium," Optics Letters, to appear.

Papers in Preparation with ONR Sponsorship

1. A. Ishimaru and R. L-T Cheung, "Light transmission and reflection in clouds."
2. A. Ishimaru, R. L-T Cheung, and Y. Kuga, "Transmission of a beam wave in a diffuse scattering medium."

Paper Presentations Related to this Contract Since September 1978

1. A. Ishimaru, "Optical scattering and diffusion in turbulence and scatterers," OSA Meeting, San Francisco, October 1978.
2. K. Shimizu and A. Ishimaru, "Estimation of size distribution of randomly distributed scatterers," OSA Meeting, San Francisco, October 1978.
3. A. Ishimaru, "Forward scatter and diffusion of pulses in a random distribution of scatterers," URSI Meeting, Boulder, November 1978.

4. A. Ishimaru, "Multiple scattering effects on pulse propagation through fog and clouds," Naval Ocean Systems Center Program Review, San Diego, November 1978.
5. A. Ishimaru, "Forward scatter theory and diffusion theory for wave in random media," Bremmer Session, National Radio Science Meeting, Seattle, June 1979.
6. A. Ishimaru, "Multiple scattering effects on backscattering of a pulse from terrain," National Radio Science Meeting, Seattle, June 1979.
7. K. J. Painter and A. Ishimaru, "Backscattered pulse shape due to small-angle multiple scattering from a slab of random medium," National Radio Science Meeting, Seattle, June 1979.
8. K. Shimizu, A. Ishimaru, and A. P. Bruckner, "Backscattering of a picosecond pulse from a dense scattering medium," National Radio Science Meeting, Seattle, June 1979.
9. R. L-T Cheung and A. Ishimaru, "Multiple scattering of millimeter waves in rain," National Radio Science Meeting, Seattle, June 1979.
10. A. Ishimaru was invited to speak at the Chemical Systems Laboratory Scientific Conference on Obscuration and Aerosol Research, U.S. Army, Aberdeen Proving Ground, Maryland, September 1979.
11. K. Shimizu, A. Ishimaru, and L. Reynolds, "Diffusion and scattering of a picosecond pulse in a dense scattering medium," OSA Meeting, Rochester, October 1979.
12. A. Ishimaru was invited to speak on "Theoretical and experimental study of transient phenomena in random media" at the workshop on "Wave Propagation in Turbulent Media," sponsored by the Mathematics Division, U.S. Army Research Office, at Virginia Polytechnic Institute, Virginia, March 24-26, 1980.
13. A. Ishimaru and R. L-T Cheung, "Multiple scattering effects on wave propagation due to rain," URSI Commission F Symposium, Lennoxville, Canada, May 1980.
14. R. Woo, A. Ishimaru, and F-C Yang, "Radio scintillations during occultations by turbulent planetary atmospheres," North American Radio Science Meeting, Quebec, June 1980.
15. A. Ishimaru, R. L-T Cheung, and Y. Kuga, "Diffusion of a beam wave in random discrete scatterers," North American Radio Science Meeting, Quebec, June 1980.
16. A. Ishimaru, "Characterization and remote-sensing of terrain," ICC '80, Seattle, June 1980.

17. A. Ishimaru, "Pulse propagation and diffusion in random media," International URSI Symposium on Electromagnetic Waves, Munich, August 1980.
18. A. Ishimaru, "A statistical model of electromagnetic interference," EMC '80, Baltimore, October 1980.

7. Remaining Funds

No unspent funds remaining at the end of the current contract period.

8. Personnel

Graduate Students:

- (a) Koichi Shimizu
- (b) Raymond Chan
- (c) João Machado
- (d) Kirk Painter
- (e) Rudolf Cheung
- (f) Yasuo Kuga

9. Graduate Students who have Earned Advanced Degrees

- (a) Kirk Painter, M.S. in E.E., Fall 1978;
now with Lockheed Missiles and Space Co.
- (b) Koichi Shimizu, Ph.D. in E.E., Summer 1979;
now with Hokkaido University, Japan.

10. Other Government-Sponsored Research

- (a) Title: Multiple Scattering Effects on Pulse Propagation and Scattering

Grant No.: ENG 77-12544

Agency: NSF

Term: January 1, 1978 to June 30, 1980

Funding: \$59,993

Principal Investigators: Akira Ishimaru and Rubens A. Sigelmann

(b) Title: Laser-Scattering Detection of Microemboli in Blood Flow-
ing over biomedical surfaces

Grant No.: 1 P01 HL 22163-01

Agency: NIH

Term: August 1, 1979 to July 31, 1980

Funding: \$33,333

Principal Investigators: Akira Ishimaru and Larry Reynolds

(c) Title: Statistical Study of Electromagnetic Interference

Grant No.: NB80RAC00012

Agency: National Bureau of Standards

Term: December 1, 1979 to November 30, 1980

Funding: \$46,221

Principal Investigator: Akira Ishimaru